STUDIES ON THE OPTIC RADIATIONS

THE SIGNIFICANCE OF SMALL FIELD DEFECTS IN THE REGION OF THE VERTICAL MERIDIAN*

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There is still a question concerning the exact course as well as the individual relationships of the fibers of the optic radiations immediately after they leave the lateral geniculate body. The same is true of the clinical effect of involvement of these fibers. The chief controversy centers around the degree of forward looping of the fibers as well as the specific relationship of fibers from corresponding retinal points. The significant clinical reference relates to the part of the visual field that is involved first by a small lesion in the mid-temporal area and whether or not such a lesion would produce a congruous or an incongruous visual-field defect. The opportunity to study this problem was made possible when it was decided to investigate a group of patients on whom temporal lobectomies were done in an attempt to control intractable seizures. It was felt that this group of patients had well defined, fairly circumscribed and identifiable lesions. Further, the extent of the lobectomy in terms of distance from the line of resection to the tip of the temporal lobe also was known. It follows that this group of patients represents individuals who have had graded resection of the temporal lobe and consequently of the forward looping of the optic radiation. Visual-field studies of these patients postoperatively would, therefore, yield information regarding the extent as well as the shape of visual defects as correlated with progressive steps of temporal-lobe resection.

There seems no longer much of a question of whether there is a "temporal Knie" of Flechsig or a "temporal loop" of Meyer- Archambault. The existence of this pathway of the optic radiations was first inferred by Flechsig in 1896. In fact, Meunert in 1884 had illustrated a considerable forward looping of the optic radiations. Then, in 1907, Meyer very strikingly illustrated this feature of the visual pathway in two brains with extensive atrophy of the temporal and occipital lobes, but with sparing of the optic radiations and optic cortex. In these cases the visual fibers stood out by themselves and clearly demonstrated an extensive forward detour of the ventral portion of the geniculo-calcarine tract. In one of the later publications of Flechsig (1920) this temporal loop was well demonstrated with Weigert's stain in a horizontal section of a brain in a 16-day-old infant. Cushing in 1922 had drawings made of various glass models constructed by Meyer. These drawings have been copied extensively and have formed, to a great extent, the classical illustrations of the geniculo-calcarine pathways. Archambault in 1909 also noticed an anterior deviation of the optic radiations. Probst in 1906 produced some of the most convincing evidence of the anterior extension of the optic radiations. He had a patient with a discrete vascular injury to the lateral geniculate body and by using Marchi's staining method he showed that the most anterior fibers of the optic radiations actually lie lateral to both the tip of the temporal horn and the amygdala. Furthermore, Pfeifer in 1925 reported from myelogenetic studies in young infants a very extensive recurrent loop. In fact, he demonstrated that it surrounded the tip of the temporal horn of the lateral ventricle. Van Buren and Baldwin in

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subsequently suggested that this relationship to the tip of the temporal horn may alter with postnatal development of the cerebral hemispheres and that in adults the loop no longer swings far enough forward to cap the temporal horn. As a matter of fact, Meyer\textsuperscript{12} previously had reported from his anatomical studies that the most anterior part of the loop does not go around, but rather that it swings just short of, the anterior end of the tip of the temporal horn. Van Buren and Baldwin felt that the relationship between the tip of the temporal horn and the optic radiations as shown by Probst explains their experiences as well as those of Fox and German\textsuperscript{6} that the temporal horn may be opened surgically without the production of a defect in the visual field. Van Buren and Baldwin did emphasize that there was a wide range of anatomical variation in this relationship.

Another method used to demonstrate not only the origin, course, and termination of the visual radiations, but also their basic internal and functional organization, has been the careful dissection or “teasing” of well fixed and hardened brain specimens. One of the greatest proponents of this was Rasmussen\textsuperscript{6} who used this technique for re-study of the question of the existence of a temporal loop. He found that after removal, by this technique, of the lenticular nucleus and after displaying the internal capsule from a lateral approach, one could demonstrate fibers that seemed to originate in the lateral geniculate body and pass out laterally and then forward around the temporal horn and then backward to become part of the optic radiations. He found from these studies that the optic fibers do loop forward, going almost, but not quite, as far anteriorly as the extreme tip of the temporal horn. They are separated from the ependyma by a thin stratum of corpus callosal fibers (tapetum) which runs at a slight angle to the optic fibers. He found that this forward looping portion of the geniculo-calcarine fibers usually proceeded forward a distance of at least 2 cm, before turning backward to join the more compact portions of the optic radiations that course directly backward from the lateral geniculate body. Rasmussen did further studies on the visual pathway, following which he concluded that in the lateral geniculate body itself the fibers from the macular region of the retina terminate in the superior and posterior part of the nucleus, fibers from the superior part of the more peripheral (extramacular) retina terminate in the medial portion and those from the inferior portion of the retina end in the lateral portion of the lateral geniculate body. Then, from the lateral geniculate body to the cerebral cortex there is a sort of untwisting of the fibers which brings the lower retinal quadrants into relation with lower half of the visual cortex (gyrus lingualis) while the upper quadrants become related to the upper half (cuneus).

The fibers relaying the macular vision are intermediate in position throughout the optic radiations and continue into the posterior third of the visual cortex (Brodmann area 17). Other studies\textsuperscript{8,19} of the visual radiations have shown that there are essentially three bundles arising from the lateral geniculate body. The lower bundle of the radiations emerges from the lateral part of the lateral geniculate body, crosses the posterior limb of the internal capsule and then swings in an anterior direction toward the temporal pole, slipping above the anterior part of the ventricle, following which the bundles then make a sharp turn laterally and backward (temporal loop) and in this way come to lie on the lateral surface of the ventricle. Gradually these bundles pass beneath the ventricle and into the inferior part of the calcarine fissure. Those bundles that form the upper segment of the radiations arise from the medial portion of the lateral geniculate body and pursue a similar spiral course above the ventricle to reach the superior portion of the calcarine fissure. The only difference is that they do not form a loop around the temporal horn; they pursue a straight course backward bending only a little medially as they enter the upper area of the calcarine fissure. There is also an intermediate or axial segment of the visual
radiations which is flanked by the upper and lower segments. It terminates in the most posterior part of the striate area. It is this intermediate or axial segment that contains the macular fibers.

**MATERIAL**

The material for this study consists of 30 patients out of a total of 100 who have undergone temporal lobectomy for control of intractable seizures in the period between July 1948 and July 1961. The operative procedure consisted of excision of varying amounts of temporal lobe. The incision was made perpendicular to the surface. The temporal horn of the lateral ventricle was entered in all of the patients included in this report. The line of incision was carried through the ventricle to emerge on the medial surface of the lobe, transecting the hippocampal gyrus a distance varying from 5.0 to 9.0 cm. from the tip of the middle cranial fossa. The incision through the lobe was done with suction dissection or with a knife. There was no electrocoagulation—cutting was done so that the area of damage adjacent to the line of incision was maintained at a minimum. An en-bloc excision of the temporal lobe was performed. If at the termination of the excision a neoplasm or vascular anomaly were discovered within the removed block of temporal lobe this case was not used in this study.

An attempt was made to measure the distance from the tip of the temporal horn to the line of incision through the ventricle. This distance varied from 1.2 to 3.2 cm. This measurement is extremely difficult to obtain, however, because of vagaries in surgical techniques. One hesitates, therefore, to vouch for its accuracy and perhaps it would be better to presume it only an estimate rather than a true measurement. Very apparent, however, to the surgeon and to others involved in the operation, was the great variation in the temporal lobe itself, in length, depth, vascular markings, and in the area occupied by the ventricle, i.e., the distance between the tip of the temporal lobe and the tip of the temporal horn.

Detailed visual fields were done in this series of patients by Dr. John Wendland or Dr. Sidney Nerenberg of the Department of Ophthalmology. They were performed as part of a fairly comprehensive preoperative and postoperative study on this selected group of patients. Other aspects, not particularly related to the present problem, but nevertheless studied, included psychometric and psychiatric investigation and audiologic studies. The only pertinence of these studies to that of the 30 patients presented here, on whom the most exacting visual fields could be outlined, was that those with the greatest psychometric and psychological capabilities certainly offered the most cooperation for this study. As a matter of fact, the entire group of people chosen for this study were remarkably cooperative and consistent in their responses.

Central visual fields were performed at 1 meter in all patients and studies of perimeter fields were done in 20 of the 30 patients. The majority were tested with four white targets ranging in size from 1 to 30 mm. All were tested with at least two white targets of varying size. Utmost care was used to outline the fields.

**RESULTS AND DISCUSSION**

Of the 30 patients, 13 had varying degrees of an upper quadrantic defect, 9 had a complete upper quadrantic defect, 2 had all of the upper quadrant and a small part of the lower quadrant involved and 6 had complete hemianopsias.

The characteristic visual-field defect (Figs. 1–9) was pie-shaped with its apex extending toward the fixation point and with one of its sides formed by the vertical meridian. The vertical margin was always extremely sharp. Invariably the area involved first was this paravertical area of the superior field. The corollary of this is that in those patients with the most minimal field defect, the defect was always along the vertical meridian. It must be remembered that in all these patients the tip of the temporal horn was entered and the least amount of excised ventricle was 1.2 cm. behind the tip.
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Fig. 1. Shaded area represents visual-field defect along vertical meridian in patient with amputation of anterior 5 cm. of left temporal lobe. Line of resection was 1.2 cm. behind tip of temporal horn. Confrontation studies alone may miss this defect; the same is true if large target is used on central fields.

The fact that the vertical margin of the field defect was always sharp, and seemingly first involved even in patients who had the least amount of the temporal lobe resected, would indicate that the fibers next to the vertical meridian and subserving the uppermost portion of the visual fields (lower retinal) loop forward farthest along the ventricle. This observation of the involvement of the defect occurring earliest in the superior paravertical area is consistent with that of Van Buren and Baldwin who also felt that the representation of the retina along the vertical meridian lies farthest forward in the optic radiations and hence makes the largest excursion into the temporal lobe.

There was a fairly close direct correlation between the extent of the lobectomy and the defect in the visual field. In general, as the amount of the excised temporal lobe increased, the characteristic pie-shaped defect with its sharp vertical meridian became larger until a complete quadrantanopsia was produced. Interestingly enough, after the defect changed, by gradual enlargement from a small pie-shaped sector defect to a quadrantanopsia, it usually converted abruptly into a complete homonymous hemianopsia. In only 2 patients did the defect extend into the lower quadrant without producing a complete hemianopsia. In no patient was a hemianopsia found without macular

Fig. 2. Amputation of anterior 5 cm. of left temporal lobe. Visual-field defect is along vertical meridian. There is a sharp vertical margin.

Fig. 3. Amputation of anterior 5\(\frac{1}{2}\) cm. of right temporal lobe. Both the vertical and horizontal margins are sharp. The ventricle was entered 1.4 cm. behind the tip.

Fig. 4. Amputation of anterior 6 cm. of right temporal lobe. The ventricle was entered 1.4 cm. behind tip. The macular area is spared and the horizontal margin is not down to the horizontal meridian, indicating that not all of the loop of Meyer-Archambault is involved.
vision involved, i.e., there was no macular sparing. It was concluded that the horizontal meridian is probably the dividing line with respect to the extent of the forward (anterior) looping of the fibers, i.e., a lesion of the most anterior fibers in the Meyer-Archambault loop accounts for a superior paravertical defect and as the lesion is extended posteriorly the inferior border of the visual defect changes its angle from an oblique to a horizontal direction from the fixation point. It was found that with progressive amputation of the temporal lobe upper quadrantic defects of increasing sever-

**FIG. 5.** #906872. Amputation of anterior 6½ cm. of left temporal lobe—1.6 cm. behind the tip of ventricle. There is no macular sparing and this is almost a complete quadrantanopsia, suggesting the macular bundle is intermingling with the loop of Meyer-Archambault.

**FIG. 6.** #848364. Amputation of anterior 7 cm. of left temporal lobe. The line of resection traversed the ventricle only 1.2 cm. behind the tip. There is a comparatively small pie-shaped superior paravertical defect coming not closer than 20° from the fixation point. This illustrated the variability in the anatomy of the temporal lobe with apparent shortening of the temporal horn of the ventricle and consequently a more posterior placement of the loop of Meyer-Archambault.

**FIG. 7.** #868193. Amputation of anterior 7 cm. of right temporal lobe transecting the ventricle 2.9 cm. behind tip. The vertical and horizontal margins are sharp; the defect is congruous and invades the macular area. Since this is not a "complete" quadrantanopsia it suggests that the macular bundle is somewhat intermixed with the fibers from the inferior extramacular retinal segment.

The result (this is not a straight-line relationship) since fibers subserving the upper visual-field quadrants are quite spread out in the temporal lobe, but the defect is always noted earliest near the vertical meridian and progresses toward the horizontal. When a complete quadrantanopsia is reached, a sharp horizontal boundary to the fields was obtained suggesting at least a slight anatomical separation of fibers subserving the upper and lower visual-field quadrants. By the same token, the abrupt conversion into an hemianopsia suggests considerable compactness of these fibers from the medial part of the lateral geniculate body as they traverse back to the visual cortex (Wendland and Nerenberg22). Also the fact that the macular fibers, which generally are thought to separate the two bundles, were always involved in a "complete" quadrantanopsia before it converted into a hemianopsia suggests that they may be blended into these two bundles.

All of the field defects in this series of patients did not extend to the fixation point. This observation has been made previously by Holmes9 (1918) who observed that quadrantic defects might or might not extend to the fixation point. Fox and German6 (1935) reported on a patient with a temporal lobectomy who had a quadrantanopsia that
came no closer than \(4^\circ\) from the fixation point. It was certainly apparent in the patients reported in the present study that the site the defect came closest to the fixation point was along the vertical meridian. It is emphasized that central fields alone may permit missing some defects and that studies of peripheral fields also are required.

All of the visual fields were found to be remarkably congruous with all targets used. The slope of the defects was extremely steep in all but 2 cases and in these it was comparatively steep. Since the visual fields in these patients were congruous, the conclusion was reached that there is no appreciable separation of fibers from corresponding retinal points in the anterior part of the radiation. This is contrary to the findings and the conclusions reached by Van Buren and Baldwin, who found the fields often to be incongruous with the larger field defect on the side ipsilateral to the lobectomy. Our observations support the findings of Rönne, Traquair, Spalding, Hughes, and Falconer and Wilson, that fibers from the corresponding retinal points do, indeed, lie in juxtaposition in the anterior portion of the visual radiations. This would seem reasonable anatomically, i.e., if fibers from corresponding retinal points were brought together in the lateral geniculate body there would be little reason for the fibers to separate again only to be brought together for a second time in the visual cortex. How then is it possible to explain the incongruity so often reported in patients with temporal-lobe tumors? The most logical explanation is that the optic tract may be affected by temporal-lobe tumors (Rönne, Traquair) since the tract lies just above and medial to the temporal lobe and the inferior lateral portion of the tract contains fibers serving the upper quadrants of the visual fields. Thus, an upper quadrantic incongruous homonymous field defect could very easily result from pressure on the tract. As a matter of fact, in patients with the usual large tumor of the temporal lobe there is no reason why either the tract or the radiations or both could not be affected simultaneously. Secondly, there is no reason to believe that there is not some normal variation in human anatomy which would permit a few vagaries in this relationship of corresponding retinal points. Thirdly, it is emphasized that the technique and cooperation of the patient are exceedingly important in assessing a visual-field defect. In many patients with temporal-lobe neoplasms who have been found to have incongruous visual-field defects, the incongruity might be caused by lack of the patient’s cooperation, i.e., lack of alertness.

**Fig. 8.** Amputation of anterior 7 cm. of temporal lobe and transection of ventricle 2.2 cm. behind tip. Again this is not a “complete” quadrantanopsia but the macular area is lost. This illustrates essentially the same as Fig. 7.

**Fig. 9.** Amputation of anterior 7.5 cm. of temporal horn; transection of ventricle 2.0 cm. behind tip. This is the characteristic quadrantanopsia observed. It is congruous, the margins are steep and the macular area is involved. With more extensive resection of the lobe this type of field defect converted, with two exceptions, into a complete hemianopsia.
SUMMARY

1. Visual-field studies on a series of 30 patients on whom varying amounts of temporal-lobe tissue were excised are reported.

2. It was found that with progressive amputation of the lobe the earliest visual-field defect always began along the superior vertical meridian. This suggested that the fibers serving the upper quadrants of the visual fields lie in the most anterior part of the temporal loop of Meyer-Archambault. The defect enlarges from the vertical to the horizontal meridian as the extent of temporal lobectomy increases.

3. These small paravertical field defects did not always extend to the fixation point, in fact, several did not extend inside the 30° range. Consequently a visual-field defect resulting from a small mid-temporal lesion may be missed unless careful studies of the perimetric fields are done in addition to the usual studies of the central fields.

4. The visual-field defects were congruous which is suggestive that fibers from corresponding retinal points lie close together in the loop of Meyer-Archambault.

5. The margin of the defect along the vertical meridian was always sharp; the margin toward the horizontal meridian was usually sharp. When the defect became a quadrantanopsia the horizontal margin was sharp, the defect congruous and extending to the fixation point. The fact that such a sharp horizontal boundary was obtained suggests at least a slight anatomical separation of the superior and inferior retinal fibers in the radiations. Once the horizontal meridian was passed a complete hemianopsia developed abruptly which suggests the fibers in the medial part of the optic radiations, i.e., from the superior retinal quadrants, are in a compact bundle.

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